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SUSQUEHANNA RIVER BASIN COMMISSION

DEC. 24, 1970

# COAL MINE DRAINAGE IN THE SUSQUEHANNA RIVER BASIN

## EXECUTIVE SUMMARY

SEPTEMBER 1973

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# SUSQUEHANNA RIVER BASIN COMMISSION

## EXECUTIVE SUMMARY

# COAL MINE DRAINAGE IN THE SUSQUEHANNA RIVER BASIN

SEPTEMBER, 1973

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Additional copies of the Executive Summary are available upon request. Copies of the report, "Coal Mine Drainage in the Susquehanna River Basin," or large colored exhibit may be purchased from the Susquehanna River Basin Commission, 5012 Lenker Street, Mechanicsburg, Pa. 17055.

# PREFACE

This Executive Summary presents, in condensed form, a review of the report "Coal Mine Drainage in the Susquehanna River Basin" prepared for the Susquehanna River Basin Commission, September 1973.

In the report all significant amounts of coal mine drainage from abandoned coal mines and the affected streams are located geographically and described in qualitative and quantitative terms. The report contains recommendations for currently feasible and applicable abatement measures which would eliminate or reduce pollution from abandoned coal mines to tolerable levels, and presents estimates of abatement costs. It also includes a section dealing with benefits that might accrue from any given abatement plan. Benefits and costs of land and stream restoration in areas affected by past mining activities are summarized and presented in chart form. From this chart the priorities for abatement work can be readily established.

The report contains a large colored exhibit showing the area of the basin underlain by coal, streams affected by acid mine drainage and streams intermittently affected by acid mine drainage.

The report "Coal Mine Drainage in the Susquehanna River Basin" brings into perspective the extent of coal mine drainage in the Susquehanna

River Basin, and will benefit all agencies, organizations and individuals who are interested in improving water quality in this basin. The report is the Commission's first step toward development of a basinwide coal mine drainage abatement plan essential to the elimination and reduction of abandoned mine drainage pollution in the basin.

For more detailed information than is presented in this brief summary, refer to the original report.

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# INTRODUCTION

Acid mine drainage from abandoned coal mines is the most serious pollution problem in the Susquehanna River Basin! This statement, although startling, is true, both in terms of water quality degradation and costs to eliminate it. It is the only significant National water pollution problem that is not the focus of a major federal action program. Present federal policy on drainage from abandoned coal mines is limited to research and demonstration activities because remedial programs are complex and costly. However, sufficient technology now exists to eliminate much of this pollution and the responsibility for abatement of mine drainage must be shared by the National Government.

Historically, coal has been mined to produce energy for the entire Nation. During the industrial revolution, coal was the primary source of energy used for production of consumer goods and for power to distribute the products across the Nation. Coal production soared during all of the Nation's war years. Even today, with the complex interconnections of giant utility lines, the Nation is still dependent, to some extent, on electricity produced with coal. Most of the mines that once produced great quantities of coal are now abandoned; however, they continue to produce acid which seriously degrades the waters of the Susquehanna River Basin. With the current energy shortfall, coal, our currently

most abundant energy resource, will be mined in increasing volumes. Some of this increased mining will help solve the abandoned mine drainage problem because miners will be reaffecting old mines and thereby become responsible for their reclamation. However, the vast majority of the acid mine drainage will have to be abated by a serious, concerted all-out effort using all the resources at our command.

Considerable progress has been made in controlling and/or eliminating pollution from municipal and industrial wastes, and from active and future mines in the Susquehanna River Basin. The full potential of this progress cannot be realized unless water quality degradation by acid discharges from abandoned mines is eliminated.

# IMPACT OF COAL MINE DRAINAGE

## SOURCES

Most of the acid mine drainage discharging to the Basin's streams is from Pennsylvania's abandoned underground mine workings. These subsurface mines were developed by driving entryways ("shafts," "slopes," or "drifts") into coal bearing rock units. The type of entry depends on the slope and location of the coal seam. A shaft entry is driven vertically down to reach coal bearing formations when coal is not exposed at the surface. Coal mined by this method is usually under the ground water table.

Slopes are entries angling downward to intercept a coal seam. A drift entry is usually driven to the rise or dip of an outcropping coal which tilts slightly from the horizontal. In the Anthracite Region "tunnels" or large haulageways are driven with a slight rise (to provide gravity drainage) into many coal seams which dip downward. While coal is being removed from the mine, infiltrating ground water is removed by gravity drainage or pumping.

If a coal basin lies above natural drainage, a water level tunnel can be driven into the lowest seam mined and provides inexpensive gravity drainage.

Many drift mines are a major and continuing source of acid mine

drainage in the Basin. When abandoned they tend to discharge poor quality water which seemingly never shows improvement.

Large overflows of mine water in the Anthracite Region have shown some slight improvement in quality since they first broke to the surface in 1961. These overflows, however, still are acidic and pollute tributary streams and reaches of the Susquehanna River. Large water level tunnel discharges from abandoned deep mine complexes comprise some of the greatest single and continuing sources of mine drainage pollution in the basin.

Surface or strip mines may be gravity drained or pumped to remove accumulated water. Efforts are usually made to direct surface water so that it does not enter the working area.

Improperly restored strip pits usually trap surface runoff. These strip mine pools often contain high concentrations of dissolved salts and are reservoirs of potential pollution. During periods of heavy rainfall, they may overflow, discharging concentrated "slugs" of acid water which severely pollutes receiving streams. Water from such impoundments frequently emerges in the form of seepage down-slope from the mining operation. Water trapped in abandoned strip pits may seep into deep mine workings, thereby adding high concentrations of dissolved solids to deep mine flows.

Leachate from coal refuse piles associated with aban-

doned mining operations commonly are sources of pollution. Refuse piles cover large areas, and along with that material spread about from spillage when transporting the waste to disposal areas, provide an extensive source of minerals which yield high concentrations of acid and dissolved salts.

The severity and distribution of mine drainage sources in the Basin can be summarized as follows:

1. The greatest source of acid mine drainage in the Basin is from numerous abandoned deep mine discharges in the Bituminous Field. These discharges show practically no water quality improvement with time.
2. Deep mine gravity discharges in the Anthracite Region are less numerous than in other areas, but contribute a much higher acid loading per discharge. In the Northern Field of this region mine pool overflows have shown some water quality improvements (less acid) with time, but remain intolerable in terms of high iron and sulfate concentrations.
3. Bituminous strip mines are more significant sources of acid mine drainage than anthracite strip mines.
4. Coal refuse is a significant source of acid and dissolved salts in many watersheds of the Bituminous and Anthracite Fields.

A tabulation of the distribution of the major types of coal mine drainage contribution is provided on the next two pages. A map showing the location of streams whose watersheds contribute significant amounts of coal mine drainage is located on page 49.

| Watershed | PERCENT OF COAL MINE DRAINAGE CONTRIBUTED BY: Deep Mines | Strip Mines | Coal Refuse |
|---|---|---|---|
| **WEST BRANCH SUSQUEHANNA RIVER** | | | |
| Upstream from Chest Creek | 28 | 2 | 70 |
| Chest Creek | 34 | 30 | 36 |
| Reach from Chest Creek to Clearfield Creek | 60 | 35 | 5 |
| Anderson Creek | 50 | 40 | 10 |
| Clearfield Creek | 75 | 20 | 5 |
| Clearfield Creek to Moshannon Creek | 70 | 20 | 10 |
| Moshannon Creek | 70 | 20 | 10 |
| Moshannon Creek to Sinnemahoning Creek | 60 | 30 | 10 |
| Sinnemahoning Creek | 70 | 20 | 10 |
| Sinnemahoning Creek to Bald Eagle Creek | 75 | 20 | 5 |
| Bald Eagle Creek to Beech Creek | 60 | 20 | 20 |
| Bald Eagle Creek to the Mouth of West Branch | 80 | 15 | 5 |
| **JUNIATA RIVER** | | | |
| Little Juniata River | 0 | 0 | 0 |
| Frankstown Branch Beaverdam Branch | 0 | 0 | 0 |

|  | PERCENT OF COAL MINE DRAINAGE CONTRIBUTED BY: |  |  |
|---|---|---|---|
| Watershed | Deep Mines | Strip Mines | Coal Refuse |
| Burgoon Run | 0 | 0 | 0 |
| Sugar Run | 90 | 10 | 0 |
| Raystown Branch |  |  |  |
| Six Mile Run | 75 | 20 | 5 |
| Shoup Run | 75 | 20 | 5 |
| Sandy Run | 80 | 20 | 0 |
| Great Trough Creek | 90 | 10 | 0 |
| Augwick Creek |  |  |  |
| Roaring Run | 0 | 0 | 0 |
| TIOGA RIVER |  |  |  |
| Morris Run | 75 | 20 | 5 |
| Cool Creek | 75 | 20 | 5 |
| Bear Creek | 75 | 20 | 5 |
| SUSQUEHANNA RIVER |  |  |  |
| Lackawanna River (Upper and Lower) | 70 | 20 | 10 |
| Lackawanna River to Nescopeck Creek | 80 | 20 | 0 |
| Nescopeck Creek | 90 | 10 | 0 |
| Catawissa Creek | 90 | 10 | 0 |
| Shamokin Creek | 80 | 20 | 0 |
| Mahanoy Creek | 80 | 20 | 0 |
| Rausch Creek | 75 | 15 | 10 |
| Wiconisco Creek | 97 | 3 | 0 |
| Swatara Creek | 70 | 15 | 15 |

## DEGRADED STREAMS AND IMPACT - BITUMINOUS COAL REGION

As indicated in the Preface, readers wishing more detailed information on the impact of mine drainage in the Basin may wish to consult the main report.

### The West Branch Susquehanna River

The Bituminous Coal Region in the Susquehanna River Basin is drained by the West Branch, Juniata, and Tioga Rivers. The West Branch is largest of the three rivers and drains 6,900 square miles. More than half this area is underlain by bituminous and some semi-anthracite coal. Extremely severe coal mine drainage pollution exists in tributary watersheds underlain by disulfide-rich coals and associated rock strata having low natural alkalinities.

Upstream from Clearfield Creek, the West Branch and its tributary streams have shown some water quality improvements in past years.

Chest Creek is degraded by mine drainage in only a few of its tributary watersheds. Anderson Creek is the only watershed upstream of Clearfield Creek with significant contributions of mine drainage. This pollution is mostly from clay and coal strip and deep mines.

Sixty thousand pounds of acid per day is discharged to the West Branch by Clearfield Creek. Mine drainage discharges can be found from

the headwaters to the mouth of Clearfield Creek. Two tributaries, Muddy Run and Japling Run, account for half the acid load recorded at the mouth of Clearfield Creek.

Numerous small tributaries to the West Branch in the reach between Clearfield Creek and Moshannon Creek contribute acid loadings to the West Branch. These acid loadings range from 3,000 to 15,000 pounds per day. The total contribution of acid in this reach is 71,000 pounds per day. Many severely degraded tributaries in this reach are underlain by highly mineralized strata which is rich in iron sulfide compounds. The contributions of acid mine drainage in this reach are surpassed only by Moshannon Creek. Abatement of mine drainage in these small watersheds will greatly improve water quality in this reach, and downstream.

Moshannon Creek is the greatest single contributor of acid mine drainage to the West Branch. Moshannon Creek receives large discharges of acid from several vast, interconnected deep mines. These are a constant source of high volumes and concentrations of acid mine drainage. At its mouth, Moshannon Creek contributes 95 to 135 thousand pounds of acid per day to the West Branch. Complete elimination of mine drainage in the Moshannon Creek Watershed will be extremely difficult and costly.

Contributions of mine drainage to the West Branch between Moshannon Creek and Sinnemahoning Creek range from moderate to

small.

Bennett Branch Sinnemahoning Creek is acid from Moose Run to its confluence with the main branch of Sinnemahoning Creek. The Sinnemahoning then becomes acid to its confluence with the West Branch (due only to the 23,000 pounds of acid per day from Bennett Branch).

Bald Eagle Creek has a high alkaline load and contributes about 130,000 pounds per day alkalinity to the West Branch. Under normal flow conditions this alkalinity neutralizes nearly all of the West Branch's acidity. Bald Eagle Creek has one tributary, Beech Creek, which is significantly degraded by acid mine drainage.

In the remaining part of the West Branch, mine drainage affects only a few small tributaries to Pine and Loyalsock Creeks.

Loyalsock Creek is only slightly affected by mine drainage occurring in the area from the Village of Lopez to Forksville. Two drainage tunnels yield 2,000 pounds of acid per day; however, at Forksville, Little Loyalsock Creek's alkalinity neutralizes this acidity.

## The Juniata River

The Juniata River drains an area of 3,400 square miles, some of which is underlain by the Broad Top Coal Field. The Northwestern part of this watershed is underlain by an edge of the Main Bituminous Coal Field. There is an acid mine drainage treatment plant located in

the Horseshoe Curve near Altoona. It is providing an economic solution for pollution from one tributary of Juniata Creek by treating this mine drainage, and by further upgrading some of the effluent for the public water needs of Altoona.

The Raystown Branch and its tributaries to the south drain the 81 square mile Broad Top Coal Field. The greatest contributors of mine drainage in the Broad Top Coal Field are from deep mine borehole overflows, and other artesian and gravity discharges.

## The Tioga River

The Tioga River drains 1,391 square miles. Headwaters of the Tioga are affected by drainage from bituminous coal beds. Coal Creek, located in the center of the coal basin, contributes 70 percent of all mine drainage entering the Tioga under low flow conditions. Elimination of mine drainage in the Tioga River is important due to federal interest in constructing two multi-purpose dams which will provide one-half million recreation days each year.

## DEGRADED STREAMS AND IMPACT - ANTHRACITE COAL REGION

The Northern Anthracite Field is drained in part by the Lackawanna River, which enters the coal field from the northeast near Forest City. The Lackawanna River above Scranton receives several large discharges from isolated mine pools. These pools contribute little acidity and do not have much effect on the River's water quality except for an increase in dissolved solids. However, near the mouth of the Lackawanna, two mine pool overflows near Duryea and Old Forge are among the greatest contributors of mine drainage in the Susquehanna River Basin. They have a combined discharge of 90,000 pounds of acid per day and degrade the Lackawanna for a distance of two miles to its mouth.

From its confluence with the Lackawanna River, the Susquehanna River retains its alkaline condition, but is seriously degraded by the heavy concentration of dissolved salts. A few miles downstream the Susquehanna receives large amounts of mine drainage from major borehole and shaft discharges. Water quality is expected to improve somewhat over the next few years, due to decreases in amounts of reactive disulfide materials, but will still remain degraded unless abatement measures are implemented. New boreholes are being placed into mine pools to reduce mine water circulation, which should result in a reduction in the concentration of acid mine drainage from the valley. Farther downstream the Susquehanna receives

its last major contribution of mine drainage from Newport Creek, which drains the southwest part of the Northern Anthracite Field. Newport Creek currently discharges an annual average of 165,000 pounds of acid per day to the Susquehanna. About half of this acid is draining from abandoned deep mines into an active mine, where it is then pumped into the creek to avoid inundation of recoverable coal reserves.

Two tributaries drain the Eastern-Middle Anthracite Field: Nescopeck and Catawissa Creeks. Both streams are affected primarily by discharge from water level tunnels. Nescopeck Creek receives one of the largest discharges of mine drainage in the Anthracite Region; the Jeddo Tunnel discharges an average of 100,800 pounds of acid per day to Little Nescopeck Creek, a tributary to Nescopeck Creek. Nescopeck Creek thus contributes over 90,000 pounds of acid per day to the Susquehanna. Under normal flow conditions the Susquehanna remains alkaline below its confluence with Nescopeck Creek. However, following prolonged low flow periods, the Susquehanna may be acid from the Wyoming Valley to a short distance below Nescopeck Creek. Catawissa Creek is affected primarily by discharges from the Green Mountain water level tunnels. Each of these contribute 5,400 pounds of acid per day to Catawissa Creek. The largest discharge of mine drainage to Catawissa Creek is from the Audenreid water level tunnel, contributing 52,900 pounds of acid per day. Sealing the Audenreid and Green Mountain Tunnels would

substantially improve the water quality of Catawissa Creek. The Western-Middle Anthracite Field is drained by Shamokin Creek and Mahanoy Creek. Shamokin Creek is affected by eight major mine drainage discharges, which total 33,400 pounds per day, and most of this acid mine drainage is not neutralized by its natural alkaline reserves. Mahanoy Creek drains the southern part of the Western-Middle Anthracite Field. It is acid in its headwaters, but contributes over 3,000 pounds of alkalinity per day to the Susquehanna.

The Southern Anthracite Field is drained by three major tributaries that are polluted in their headwaters: Rausch Creek, Wiconisco Creek, and Swatara Creek. Currently, repairs are being completed on a lime neutralization plant which was damaged by runoff during tropical storm Agnes in 1972. This plant will neutralize most of Rausch Creek's acid. Wiconisco Creek is affected by gravity discharges from several mine tunnels. Alkaline discharges completely neutralize this acid and it ultimately discharges 6,700 pounds of alkalinity per day to the Susquehanna. Swatara Creek, which drains nearly 600 square miles, is only affected by acid drainage in its headwaters. Sediment discharges are also a pollution problem in the northwestern headwaters of Swatara Creek. Abatement here and elsewhere in the Anthracite Region will be costly on a per acre basis, compared to other areas in the Basin.

# IMPACT OF SEDIMENTATION

Sediment - in the form of sand, silt, clay, fine coal, and other solids washed off the land surface into streams and waterways, is one of the Nation's largest pollutants. In the United States, $125 million are spent each year dredging sediment from harbors, reservoirs, and waterways, and it causes a $100 million economic loss each year by reducing reservoir capacities. Streams containing excessive sediment are aesthetically unappealing, reduced in use, and aquatic life is degraded.

Although considerable amounts of sediment are carried from farms and strip mines, the greatest single contributor of sediment is urbanization, followed closely by highway construction. Intolerably high rates of sediment deposition affect the Susquehanna Basin. An average of 3 million tons (110 tons per square mile) of suspended sediment is transported annually by the Susquehanna. Of this amount 1.8 million tons are transported to the Chesapeake Bay.

Evidence exists that there has been a decrease in the rate of sediment discharge in the Basin. Since 1954 the Pennsylvania Power and Light Company has dredged up to 1 million tons of coal-laden deposits annually from Lake Clarke. In 1972 high stream flows deposited only sufficient coal to permit the recovery of 350,000 tons of coal fines. The Company has stopped coal-dredging operations after 1973 due to decreases

in annual coal deposition. Decreased mining activities and enforcement of waste disposal laws have contributed much toward reducing sediment loads associated with anthracite coal production.

In some strip mined areas annual sediment yields may exceed 15,000 tons per square mile per year, more than a thousand times the normal for undisturbed and forested land. However, average annual yields of 550 to 650 tons per square mile are more characteristic of areas where strip mining has destroyed forest cover.

Twenty percent of the sediment discharged to the Susquehanna is from areas associated with coal mining operations. Thirteen percent (or 390,000 tons) of this sediment consists of coal fines. About 300,000 tons are dredged from the river, and the remaining 90,000 tons are transported to the Chesapeake Bay annually.

# COSTS OF RECLAMATION

## PREVENTIVE MEASURES

### Surface Restoration

The primary purpose of surface restoration after mining is to limit formation of acid water. The secondary purpose of surface reclamation is to restore utility and value to the land. Surface reclamation reduces formation of acid mine drainage by promoting: 1) rapid runoff, thereby decreasing infiltration; 2) vegetative consumption (transpiration); 3) near surface moisture retention with eventual evaporation; and 4) reducing free air oxygen contact with acid-forming materials.

Open Pit mining in the nearly vertical seams of anthracite coal creates a special problem for restoration. Removal of the coal leaves large void spaces; these spaces may be partially filled by slides of unmined coal and loose rock. These "crop falls" permit extensive water infiltration. Sufficient material to properly backfill these strip mines is usually costly to obtain, thus extensive water infiltration into the pit and into deep underground workings occur.

A 20 to 70 percent reduction of acid mine drainage can be achieved by surface restoration, depending on how successfully infiltration volumes

can be reduced. In most cases, abatement projects realize a 25 percent effectiveness value for areas containing coal seams of relatively high amounts of disulfide minerals. Abatement as high as 70 percent can be obtained if the underlying seams which receive infiltration have not been deep mined extensively, or if the coals contain only moderate amounts of disulfide minerals.

Cost estimates in the following sections are based on reasonable compensation to construction companies to reclaim abandoned strip mines. Many acres of old strip mines are and will be restripped, depending on the coal market and State and Federal regulations. Pennsylvania's strip mine operators are currently restoring over 15 square miles of old strippings annually. Current cost to strip mine operators, for reclamation work as required by law in Pennsylvania, is estimated at $300 to $500 per acre. With proper planning, old strippings adjacent to those being reworked often can be reclaimed along with the active sites.

## Backfilling and Regrading

Many variables determine costs of backfilling and regrading, including topography, type of strip mining, coal seam thickness and orientation, acid potential of coal refuse or spoil, accessibility of the area, availability of on-site materials, and the season of the year the work is done.

Analysis of all methods of backfilling and regrading indicate an average cost of $860 per acre. However, contour-terrace methods, which are aesthetically more appealing, cost $1,250 per acre. These do not include costs for revegetation.

Access road construction, plus clearing and grubbing, is included in the $1250 per acre value. Stream diversion costs range from $12 to $27 per linear foot. Costs vary due to depth of cut, amount excavated, and materials used. Planting costs are not included in these linear foot prices.

## Refuse Bank Contouring and Grading

Costs for refusebank contouring and grading given here do not include costs of revegetation, sealants, clearing and grubbing, or access road construction. Refusebank contouring and grading costs $1,000 per acre, or an average 75¢ per cubic yard. Soil cover for graded refuse banks averages $2,500 per acre or $3.00 per cubic yard. Additional uses derived from removal of refuse material are secondary coal recovery, base material for roadways, anti-skid uses, and production of brick. These benefits could substantially reduce the $1,000 per acre cost.

## Clearing and Grubbing

A wide range of values exist here: $33 to $700 per acre, with a mean value of $200 per acre. Factors which vary the cost are amount of solid waste present, topography, and size-growth density. Costs can be reduced by cutting pulpwood and chipping for mulch (which also eliminates costs of burying and burning).

## Revegetation

Success of surface restoration ultimately depends on establishing a healthy vegetative cover. The main purpose of vegetation is to retain and consume that part of a rainfall which would otherwise infiltrate and increase acid mine drainage production. A vegetative cover blocks the flow of oxygen to acid forming materials, and prevents erosion and siltation.

Most State reclamation laws now require replacement of topsoil after surface mining operations are completed. This increases the number and varieties of plant types which can be successfully seeded.

General considerations for revegetating should include soil or slope stability, proper long term pH response, proper nutrients, soil moisture and temperature, and natural plant succession. Specific considerations may include: application of fly ash to increase buffering capa-

city of spoils (fly ash properties vary); realization of maximum pH's by prolonged liming of spoil; limiting velocity of water draining from an area; soil testing for lime and nutrient requirements after grading; determining drainage and moisture retention characteristics or porosity of soil; finding the organic and toxic salt content; designing the seed mixture and mulching; utilizing existing climate to the best advantage; and consideration of wildlife needs.

Based on a wide variety of soil treatment and seeding projects, analysis of past data indicates an average cost of $350 to $400 per acre.

## Mine Sealing

Abandoned deep mines are the greatest single sources of untreated acid mine drainage. Most discharges are emanating from deep mines which have ceased to operate for many years.

One type of mine seal placed in an opening is called a dry seal. This seal is used to prevent free passage of air and water into the mine and, to some extent, can be considered a water diversion technique. These seals are used where there is only a slight possibility of a hydraulic head forming behind the seal.

Recent advancements in the field of mine sealing have developed around a hydraulic mine seal. Hydraulic seals are placed at a gravity

discharge point and stop further passage of water from the mine. Consequently, the mine pool rises behind the seal, flooding the mine workings and reducing formation of acid drainage. The hydraulic head which develops behind the seal should be controlled by overflow mechanisms in the event the seal could not withstand the total head of water developing in the mine.

The highest percent of success in placing seals comes from constructing them from within the mine. If the opening is not accessible, seals must have bulkhead and grouting materials placed via boreholes from the ground surface.

Hydraulic seals for inaccessible mines range from $15,000 to $20,000 each, including 100 linear feet of curtain grouting, 50 feet horizontally on both sides of the seal.

## TREATMENT

Treatment as an abatement or control measure should only be applied after preventive measures, which have minimal or zero annual maintenance cost, are applied to the fullest extent possible. Preventive measures obtain an average reduction in acidity (effectiveness) of 25 to 70 percent for full surface restoration, and 70 percent for hydraulic mine sealing. Treatment methods offer 100 percent effectiveness, but at the

greatest long-term cost.

A large number of watershed studies have indicated neutralization is the cheapest treatment method. Neutralization techniques are developed around mixing a chemically basic substance with acid mine drainage to neutralize the acid and precipitate salts. Although more than a dozen common neutralizing agents exist, only lime, limestone, and a combination of both have been extensively used.

Type and availability of a neutralizing agent must be taken into account. Resultant hardness or increased solids (dissolved or undissolved) in the effluent should not exceed limits set by law. Natural alkalinity in a region should be used to abate acid mine drainage if possible. After a period of 10 to 15 years cumulative operating costs can equal or begin to exceed initial costs due to annual labor and material expenditures.

## Lime Neutralization

Most acid mine drainage treatment plants in the Susquehanna Basin use hydrated lime as a neutralizing agent. However, it is expected that future plants may use a lime-limestone combination method. Many of the plants now in use were the first ever to be constructed, and their planning lacked information that was subsequently gained through their operation.

Hydrated lime treatment process involves neutralization, aeration

(oxidation of ferrous to ferric iron), clarification or thickening, sludge dewatering, and sludge disposal. Advantages of using lime are availability, lower amount of dissolved salts, and the physical properties making it amenable to mechanical manipulation.

Quality of a discharge is slightly more important than quantity in determining treatment cost. Topography, geology and availability of land must be considered in determining the nature of the treatment facilities to be built.

## Limestone Neutralization

Use of limestone reduces size and space requirements for settling basins due to reduced volumes of sludge, as compared with pure lime treatment. Other advantages are lower cost of the neutralizing agent and safer handling characteristics. Limestone, however, does not oxidize ferrous iron rapidly. Other costly construction is required to overcome this shortcoming. Detailed cost data can be obtained from the Appalachian Regional Commission's 1973 report titled "Analysis of Pollution Control Costs."

## Lime-Limestone Neutralization

The combination method, using both lime and limestone as neutralizing agents, exploits their individual primary advantages and avoids

some of the disadvantages of each. For example, limestone cannot rapidly oxidize ferrous iron above a pH of 7. At lower pH's limestone is more economically effective. Full utilization of lime, especially in the lower pH ranges, creates a voluminous sludge problem which can be alleviated by using limestone or other more costly techniques. This combination method, relative to use of a single agent, has reduced material costs 25 percent for pH up to 6.5, and decreased sludge volumes up to one third of that accumulated for comparable lime neutralization.

As the ratio of lime over limestone raw material cost exceeds 1.8:1, additional cost reductions are achieved. The reverse is true as the ratio becomes less. Although initial costs of a combination treatment plant are greater, lower costs of materials should produce lower long-term cost. Cost data for increased efficiency lime-limestone treatment can be found in the 1973 Appalachian Regional Commission report on "Analysis of Pollution Control Costs."

## BENEFITS OF RECLAMATION

The most pollution-sensitive water use is fishing. Damage to fish and fish food organisms is usually caused by high concentrations of acid, iron, sulfate, and deposition of a smothering blanket of precipitated iron salts and sediment in stream beds. Destruction of aquatic life and discoloration of water and stream bottoms make streams and impoundments aesthetically unappealing to most persons.

Coal mine drainage has a definitely adverse effect on use of streams for industrial, municipal, and agricultural (livestock) water supply. In water treatment plants, high acidity and low pH may result in adverse effects on chemical coagulation, softening, and corrosion control. Telephone and electrical services are seriously hampered when acid mine drainage contacts buried transmission lines.

Iron and manganese cause serious problems in public and industrial water supplies, staining plumbing fixtures and laundry and interfering with industrial processes. Iron supports growth of filamentous bacteria, which restrict and even stop flow of water in distribution lines. Some sulfate compounds produce permanent hardness in water. Hardness is objectionable in public supplies, because consumers are forced to use more soap for cleaning purposes or pay for softening. Permanent hardness in boiler feed water forms scale, which cuts down on heat exchange efficiency of

boilers.

Use of mine drainage for crop irrigation tends to increase the acidity of normally acid soils in the Basin. Milk production is seriously affected when cows consume water containing acid mine drainage.

All benefit dollar values estimated for this report do not take into account generation of an additional $3 to $4 of business for each immediate benefit dollar. This is referred to as the multiplier effect.

## HUNTING AND FISHING

During 1970, some 30 million fresh water fishermen spent 3.7 billion dollars on 592 million recreational days, or $6.30 per day. Twelve million small game hunters spent nearly one billion dollars for 124 million recreational days, or $7.62 per day. About 7.8 million big game hunters spent nearly one billion dollars on 55 million recreational days, or $17.47 per day.

Pennsylvania and New York State have the lowest percentage of their residents going fishing, as compared with other regions in the United States. Fishing in nine different areas in the United States ranged from 14 to 31 percent of the resident population. The Pennsylvania-New York area also has the lowest percentage of its residents classified as hunters. Only six percent of this area's population hunt. Percentages throughout the United States range from six to 17, with a mean value of ten. These

low percentages indicate that increased recreational facilities are needed and will probably be utilized when available by potential hunters and fishermen.

More than 216 million dollars were spent hunting big and small game in Pennsylvania by residents and non-residents in 1972. The Commonwealth has an area of 45,333 square miles; eighty percent, or 23 million acres, is potential game land. For each acre of game land, an average of $9.32 was spent by Pennsylvania sportsmen. This is approximately equivalent to the expenditures made by big and small game hunters during a one-year period for clothing, food, lodging, auto expenses, licenses,guns, ammunition and other miscellaneous items. This is used to estimate the value of one acre of reclaimed land for hunting benefit purposes.

Reclamation on strip mined land also provides increased hunting potential and benefits in adjacent lands. However, these benefits are not used to establish higher benefit/cost ratios, since unreclaimed strip mines presently support some wildlife activity.

## RECREATION AND AESTHETICS

"Aesthetics" may not convey exactly the same meaning to each individual, but it does relate to a person's general perception and appreciation of nature and its beauty. Antique shops, mass urban to rural

movement, art museums, national forests and parks, all testify to our common everyday interest in aesthetics. During summer months, tourist activities in western United States and other localities are alive with interest centered around the aesthetic enjoyment of nature.

A purely objective monetary evaluation of aesthetics is extremely difficult, and perhaps never to be achieved, without some assumptions being made. There may easily be as many different monetary evaluations placed on aesthetics as there are concerned taxpayers and voters. Aesthetics can best be evaluated using known dollar relationships with the pure enjoyment of nature. These dollar values can then be associated with the value of restored lands and waters.

Three forms of recreational activities have been surveyed: nature walks or hiking; wildlife photography; and birdwatching. During 1970, throughout the United States, 27 million citizens spent 337 million recreational days nature walking. About 4½ million spent 38 million days photographing wildlife. Another seven million spent 411 million recreational days birdwatching. These activities all require expenditures for equipment, transportation, and food. On a national basis,at least 786 million recreational days were spent during 1970 on purely aesthetic activities. This compares with only 178 million recreational days spent big and small game hunting during 1970. The larger number of recreational days spent on aesthetic type activities is mainly due to the lack of time restrictions or open

seasons. Aesthetic type acitivities can be enjoyed in many ways twelve months of the year, as opposed to about two months for big and small game hunting.

Using the $80 per year per person expenditure, as surveyed by the U.S. Department of the Interior, 791 million dollars are estimated to have been spent during 1970 by all persons actively pursuing aesthetic activities in Pennsylvania. This amounts to $30 per acre per year, assuming 90 percent of Pennsylvania's area can be utilized for aesthetic enjoyment.

A value of $30 per acre per year is very likely an underestimation of the aesthetic value of one acre of reclaimed land. This is because it was derived only from persons actively pursuing aesthetic activities. This value does not consider persons passively interested in an area's natural beauty. Such individuals may be traveling through an area, or spending a brief period of time near devastated lands for other purposes.

Stream non-fishing recreational improvement benefits are computed on a basis similar to land improvement aesthetic benefits. Little recreational uses occur on or near polluted streams. Land values along the banks of polluted streams are far below similar stream bank land values for non-polluted streams. This is evidenced by the number of recreational (second) homes on non-polluted versus polluted streams.

The West Branch Basin is a good example. Recreational homes

dot the banks of non-polluted streams such as First Fork Sinnemahoning, Loyalsock, and Pine Creek. Conversely, there are very few cabins located on polluted portions of the West Branch, or on Clearfield and Moshannon Creeks. A non-fishing recreational improvement value of $30 per acre is assigned to stream bank lands. This value is the same as that applied for restoration of strip mined land.

It is assumed this improvement benefit will apply to all lands within 600 feet of a reclaimed stream. This translates to 145 acres of land per mile of reclaimed stream. The applicable benefit value will then be approximately $4,400 per mile of reclaimed stream per year.

## AGRICULTURAL

There are numerous examples of strip mined land being restored for agricultural use. The potential agricultural value of an acre of land depends on rainfall rates, soils, material nutrients and soil reaction with regard to pH, slope, drainage or moisture capacity, and general agricultural economics. Only a small percent of the land in the Anthracite and Broad Top Coal Fields contains soils which are suitable for agricultural purposes. Special soil treatment could, however, increase this percentage factor for these areas and for others in the West Branch and Tioga River coal measures as well.

The least productive areas are usually forested or occupied by

poor pasture lands. The West Branch area is, relatively speaking, the most potentially productive area and has many acres of land suitable for corn, grain, vegetables and pasture. The Tioga River Basin is not as potentially productive as the West Branch, but does have areas suitable for hay, pasture, potatoes, small grain, and buckwheat.

Farmers and other agriculture experts agree that the average annual gross crop value of $100 per acre represents a realistic and conservative dollar evaluation of one acre of farm land per year. Consideration was given to the percentage of reclaimed lands which would potentially be suitable for agricultural purposes. To conservatively estimate these benefits, a minimum percentage value of two is utilized for the Broad Top and Anthracite Fields, and five percent applied to the remaining coal fields. Most experts believed these percentage values could be increased if more money was spent on regrading and soil treatment.

## SEDIMENT REMOVAL

Sediment in streams is often tolerated for long periods of time until hardships or damages arise. Restrictions in stream channels filled with sediment often cause flooding during high flows. Many areas in the Basin, which were severely affected by flooding during tropical storm Agnes in 1972, could have been spared some of this damage if excessive deposits of sediment had not been present in stream beds. In the Chesa-

peake Bay sediment interferes with navigation, which necessitates dredging. Sediment also affects aquatic life in the Bay.

An average annual load of 0.85 tons of sediment per acre is transported from strip mines in the Basin. In some cases, removal expenditures from $2.00 to $4.00 per ton can justifiably be made in the Basin. For benefit purposes in this study, a conservative estimate of $1.00 per ton of sediment removal will be utilized. Hence, for each acre of land restored, a benefit of 85¢ per acre per year is applied. A low value of $1.00 per ton was also chosen because strip mines are not the only source of intolerable amounts of stream sediment.

## TIMBER SALES

A one-acre stand of timber, which would yield 10,000 board feet, will accumulate a value of $300 to $500 every 80 years, with proper management. For benefit estimates an average value of $5 is applied to one acre of reclaimed land annually. Accumulating timber benefits are made for a thirty-year period, since strip mines undergo some natural revegetation within this period.

## RECLAIMED LAND VALUES

Rough mountain land near or in areas which have been affected by mining operations, have no sewage, water or other utility services of-

ten sell for $200 to $300 per acre or less. Land within the same area with a natural mountain setting, sought primarily for cabin sites, often sells for $600 to $700 per acre. These value increases are related to, and correlate well with, the annual dollar value placed on aesthetics for each acre of fully reclaimed land. In relatively high population density areas, restored lands are utilized for expansion, industrial parks, and public utilities.

The benefit dollar value developed in this section is the increased market value, or sales price, realized by the owner. This will attempt to reflect the minimum increased market value restored lands will eventually achieve, and is pro-rated at $5 per year per acre for 30 years.

An estimation of increased taxes is difficult to establish. True market values and the market values used for assessment purposes are often far apart. Conservative land market values, percentages of assessed market values, and applied millage rates approximating those of Clearfield County, Pennsylvania, are used to establish benefit tax dollar values in the Basin. Using an increased market value of from $250 to $400 per acre, an assessment of 40 percent, and a combined school and county mill rate of 67, increased taxes are $4 per acre.

## STRUCTURAL AND INDUSTRIAL

The Basin's economic progress is dependent on a plentiful and

readily available supply of water, with quality suitable to meet everyday needs and increasing industrial demands. Nationwide industrial water needs, also reflected by Basin needs, are greatest for production of electrical power. This has almost doubled in demand in the past ten years. This industry requires 70 percent of all water currently withdrawn for industrial use. Iron and steel production, chemical and allied products, paper products, and petroleum refining, combined, use another 20 percent. The remaining 10 percent is used for production of other diversified products.

Most water withdrawn for industrial use is returned to waterways, and only six percent is actually lost or incorporated in the product. Although our streams carry a more than adequate supply of water for future needs, some areas may not have enough water of suitable quality.

Needs for good quality water go beyond avoiding extra expense by industry to minimize plant facility damages. Damage occurs to dams, bridges, conveyance systems and other structures which cannot tolerate acid waters unless costly corrective measures are taken.

Electrical generating plants incur the highest additional costs due to acid mine drainage, at one-half percent of annual production costs. A 30 percent reduction acid mine drainage would result in a 43 percent annual treatment savings to industry. An additional 30 percent reduction in mine drainage would result in an added 37 percent savings, for a total of 80 percent annual savings. Maximum savings would occur with a 90 per-

cent reduction in acid mine drainage.

The following list summarizes benefits or savings to the various major industries for the Anthracite and the Bituminous Regions in the Susquehanna River Basin.

ANNUAL SAVINGS WHICH WOULD ACCRUE TO MAJOR INDUSTRIES
FROM REDUCTIONS OF 60% IN ACID MINE DRAINAGE

Dollars – June 1973

| Area | Food | Textile | Paper | Chemical | Glass | Metal | Electric | Total |
|---|---|---|---|---|---|---|---|---|
| I | 4080 | 2040 | 410 | 1090 | – | 140 | 8160 | = 15,920 |
| II | 4080 | 4080 | – | – | – | – | 8160 | = 16,320 |
| Total | 8160 | 6120 | 410 | 1090 | | 140 | 16,320 | 32,400 |

Area I – Anthracite Region (Main and North Branch Susquehanna River Basin)

Area II – Bituminous Region (West Branch Susquehanna River Basin)

Total annual savings in the Anthracite and Bituminous Regions to these industrial users of acid mine drainage polluted waters alone are $15,920 and $16,320 respectively. For a period of thirty years, savings (based on June 1973 dollars) are $477,600 and $489,600 respectively. These projected savings are based on current industrial use and do not include accelerated use. Although acid mine drainage treatment costs to industries will later be reduced due to new technological innovations, increased costs to industry from greater production and new industries in the Basin

should have a compensating affect.

In addition to the costs to industry, relatively substantial costs for special materials which tolerate acid mine drainage are incurred periodically. Since 1970, eight bridges were constructed in the West Branch which required vitrified clay liner plates at a cost of $25,000 for all eight bridges. One recent project required a cost increase of $30.00 for a special treatment of culvert pipes designed to tolerate acid mine drainage. Based on these costs, benefits are assigned according to reduction in acid mine drainage and its associated corrosive effects. Reaches of streams which normally have pH values above 5.2 are not assigned benefits.

# BENEFIT/COST RATIOS AND PRIORITIES

Several acid mine drainage abatement methods of known cost and effectiveness were examined for applicability to a particular watershed's pollution problems. Usually a combination of methods is recommended for a single watershed. Preventive methods are recommended first, with follow-up treatment being considered only to the extent economically feasible. All costs and benefits are referenced to June 1973.

Abatement recommendations for watersheds which have not had intensified engineering feasibility studies are made by comparing costs and abatement methods with watersheds of similar drainage area, mining, and hydrogeology. Recommendations for millions of dollars worth of treatment, which is difficult to match with benefits, were not made for watersheds known to have acid mine drainage conditions for which feasible preventive methods are not yet available. Complete surface restoration of all strip mines in a watershed is not recommended due to diminishing pollution reduction returns or corresponding benefits.

A factor which may have a considerable influence on costs for abatement of acid mine drainage within the next thirty years is the economic future of the coal industry in connection with fossil fuel needs. Projected energy requirements within this period will require increases in environmentally safe coal mining, preparation, and utilization. Remaining or

partially mined coal reserves which currently form acid mine drainage will, to some extent, be recovered. Old unreclaimed strip mines, adjacent to future workings, will be restored, resulting in fewer eyesores and less pollution.

New technological developments which permit utilization of higher sulfur coals will also increase removal of some acid forming coals. Numerous coal refuse piles now causing stream pollution could be converted into useful products or energy and aid in promoting sound economic growth within regions of the Basin which are now economically depressed.

All benefits are projected for a 30 year period. However, it should be recognized that most of the benefits will accrue for a much longer period than thirty years. These dollar values for a wide range of benefits provide an absolute scale from which desirability of performing reclamation can be judged in concert with other environmental programs. These programs will require evaluation of specific land and water uses, acreage of affected land reclaimed by future strip mining operations, and natural resource requirements.

In establishing benefits on a local and comprehensive basis several basic considerations were used:

1. Upstream reductions in acid loading, to varying degrees, always result in downstream increases of alkalinity.

2. Tributaries discharging large acid loadings cannot be excluded from a comprehensive program, and damages caused by these watersheds should be proportioned to include damages caused to receiving streams.

3. Main stream tributaries with small acid loading and some natural alkalinity accrue local benefits after reclamation, but contribute less to a comprehensive abatement program.

4. Main stream tributaries with severe and widespread acid mine pollution, and little natural alkalinity, are unlikely to accrue local benefits, but will accrue large downstream benefits. These watersheds have high comprehensive priorities relative to their local priority rankings.

Stream oriented benefits (fishing, non-fishing stream bank aesthetics, and structural damages) vary greatly and depend on severity of a stream's pollution and its potential for supporting a sport fishery. Land oriented benefits for one acre of reclaimed strip mine total $59 per year. Present land restoration costs in the Bituminous and North-Central Fields can be equaled by land improvement benefits in 34 years without regard to water quality improvements.

Addition of stream oriented benefits will greatly decrease the time span over which benefits must be computed to make a project economically viable. Current costs for complete surface restoration in the Anthracite Region, where abatement is more costly, can be matched by land oriented benefits within 76 years. Substantial stream benefits also decrease this time requirement.

Priority rankings are established by evaluating benefit/cost ratios for the first year, and for the first 30 years. Priority evaluations using the accumulative time period avoid low priority rankings of watersheds which have low first-year benefit/cost ratios.

The following chart lists all watersheds with their abatement costs and benefits. Chest Creek is ranked highest primarily due to coal mine drainage which can be abated at low first cost. The Tioga River is also ranked high, due mainly to federal interest in a large multi-purpose (recreation) flood control dam.

Abatement of coal mine drainage in the Chest Creek to Clearfield Creek reach of the West Branch will greatly expand recreational potential around the Curwensville Dam area. From Bald Eagle Creek to the mouth of the West Branch, relatively small expenditures will completely restore streams which are moderate to weakly acid. Abatement in local priority watersheds ranked 6 through 9 will eliminate most of the mine drainage entering the West Branch.

Within the Anthracite Region, Swatara and Catawissa Creeks have the highest priority due mainly to state interest in a multi-purpose dam on the Swatara and the successful sealing of water level tunnels should eliminate most pollution from Catawissa Creek. Remaining priorities in the Anthracite Region are low, on a comprehensive basis, due to high treatment costs and difficulties in abating large amounts of mine drainage from extensive mine pool complexes.

# BENEFITS AND COSTS ASSOCIATED

| | | WATERSHEDS | RECL-AIMED ACREAGE | ABATEMENT COSTS | | | DOLLAR VALUE OF STREA | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Initial Preventive (million $) | Initial Treatment (million $) | Annual Treatment (thousand $) | Fishing | Non-Fishing | Structur |
| BITUMINOUS COAL REGION | TRIBUTARIES OF THE WEST BRANCH SUSQUEHANNA SUB-BASIN | UPSTREAM FROM CHEST CREEK | 4,000 | 12.0 | 0 | 0 | 16,950 | 325,600 | 1,0 |
| | | CHEST CREEK | 1,388 | 2.5 | 0 | 0 | 8,800 | 30,800 | 3 |
| | | CHEST CREEK TO CLEARFIELD CREEK | 1,388 | 2.5 | 0 | 0 | 124,650 | 88,000 | 5 |
| | | ANDERSON CREEK | 1,900 | 3.8 | 0.3 | 58 | 24,250 | 88,000 | 2 |
| | | CLEARFIELD CREEK | 7,220 | 13.0 | 4.4 | 400 | 270,400 | 651,200 | 3,0 |
| | | CLEARFIELD CREEK TO MOSHANNON CREEK | 9,000 | 18.0 | 0 | 0 | 38,000 | 140,800 | 3,4 |
| | | MOSHANNON CREEK | 6,000 | 12.0 | 0 | 0 | 18,700 | 176,000 | 5,0 |
| | | MOSHANNON CREEK TO SINNEMAHONING CREEK | 2,100 | 5.0 | 0 | 0 | 87,800 | 110,000 | 6 |
| | | SINNEMAHONING CREEK | 4,500 | 9.0 | 1.5 | 400 | 259,600 | 492,800 | 1,6 |
| | | SINNEMAHONING CREEK TO BALD EAGLE CREEK | 4,500 | 9.0 | 1.5 | 400 | 220,200 | 132,000 | 1,2 |
| | | BALD EAGLE CREEK | 8,000 | 16.0 | 7.7 | 900 | 54,725 | 242,000 | 8 |
| | | BALD EAGLE CREEK TO MOUTH OF WEST BRANCH | 1,944 | 4.1 | 0.7 | 200 | 507,100 | 176,000 | 4 |
| | | TOTAL (WEST BRANCH) | 51,940 | 106.9 | 16.1 | 2,358 | 1,631,175 | 2,653,200 | 18,0 |
| | SINGLE SUB-BASINS | JUNIATA RIVER | 850 | 1.5 | 1.6 | 320 | 2,050 | 268,400 | 8 |
| | | TIOGA RIVER | 1,000 | 2 | 2.2 | 440 | 50,350 | 180,400 | 1,0 |
| ANTHRACITE COAL REGION | TRIBUTARIES OF THE NORTH AND MAIN BRANCH SUB-BASIN | LACKAWANNA RIVER | 800 | 4.0 | 2.9 | 600 | 17,850 | 180,400 | 5,0 |
| | | WYOMING VALLEY LACKAWANNA TO NESCOPECK | 1,200 | 6.0 | 4.4 | 1,000 | 41,550 | 220,000 | 6,0 |
| | | NESCOPECK CREEK | 1,400 | 7.0 | 2.2 | 400 | 96,250 | 145,200 | 9 |
| | | CATAWISSA CREEK | 500 | 5.0 | 0 | 0 | 107,100 | 206,800 | 8 |
| | | SHAMOKIN CREEK | 1,200 | 6.2 | 2.2 | 400 | 86,650 | 202,400 | 1,2 |
| | | MAHANOY CREEK | 1,600 | 11.0 | 2.9 | 400 | 143,400 | 286,000 | 1,00 |
| | | RAUSCH CREEK | 310 | 1.4 | 2.2 | 300 | 42,750 | 132,000 | 7 |
| | | WICONISCO CREEK | 659 | 3.41 | 0.47 | 50 | 2,650 | 74,800 | 6 |
| | | SWATARA CREEK | 2,468 | 15.18 | 2.52 | 348 | 58,550 | 250,800 | 8 |
| | | TOTAL ANTHRACITE REGION | 10,137 | 59.2 | 19.8 | 3,498 | 596,750 | 1,698,400 | 17,00 |
| | | **GRAND TOTAL** | 63,927 | 169.6 | 39.7 | 6,616 | 2,280,325 | 4,800,400 | 36,80 |

# WITH LAND AND STREAM RESTORATION

| RIENTED BENEFITS | | DOLLAR VALUE OF LAND ORIENTED BENEFITS | | | | | | SUMMARY OF BENEFITS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sediments | Total | Land & Tax | Agriculture | Timber | Hunting | Recreation & Aesthetics | Total | Total Benefits (million $) | | Benefit/Cost Ratio | |
| | | | | | | | | 1yr. | 30yrs. | 1yr. | 30yrs. |
| 3,400 | 346,950 | 36,000 | 20,000 | 20,000 | 37,280 | 120,000 | 233,280 | 0.56 | 16.80 | 0.05 | 1.40 |
| 1,180 | 41,080 | 12,492 | 69,400 | 69,400 | 12,936 | 41,640 | 205,868 | 0.25 | 7.41 | 0.10 | 2.96 |
| 1,180 | 214,330 | 12,492 | 69,400 | 69,400 | 12,936 | 41,640 | 205,868 | 0.42 | 12.60 | 0.17 | 5.04 |
| 1,615 | 114,065 | 17,100 | 9,500 | 9,500 | 17,708 | 57,000 | 110,808 | 0.22 | 6.75 | 0.05 | 1.16 |
| 6,137 | 930,737 | 64,980 | 36,100 | 36,100 | 67,290 | 216,600 | 421,070 | 1.35 | 40.55 | 0.08 | 1.38 |
| 7,650 | 189,850 | 81,000 | 45,000 | 45,000 | 83,880 | 270,000 | 524,880 | 0.72 | 21.45 | 0.04 | 1.20 |
| 5,100 | 204,800 | 54,000 | 30,000 | 30,000 | 55,920 | 180,000 | 349,920 | 0.55 | 16.65 | 0.05 | 1.38 |
| 1,785 | 200,185 | 18,900 | 10,500 | 10,500 | 19,572 | 63,000 | 122,472 | 0.32 | 9.70 | 0.06 | 1.94 |
| 3,825 | 757,825 | 40,500 | 22,500 | 22,500 | 41,940 | 135,000 | 262,440 | 1.02 | 30.60 | 0.09 | 1.36 |
| 3,825 | 357,225 | 40,500 | 22,500 | 22,500 | 41,940 | 135,000 | 262,440 | 0.62 | 18.60 | 0.06 | 0.83 |
| 6,800 | 304,325 | 72,000 | 40,000 | 40,000 | 74,560 | 240,000 | 466,560 | 0.77 | 23.13 | 0.03 | 0.46 |
| 1,677 | 685,177 | 17,766 | 98,700 | 98,700 | 18,398 | 59,220 | 292,784 | 0.98 | 29.34 | 0.20 | 2.72 |
| 44,174 | 4,346,549 | 467,730 | 473,600 | 473,600 | 484,360 | 1,559,100 | 3,458,390 | 7.78 | 233.6 | 0.08 | 1.82 |
| 721 | 271,971 | 7,650 | 1,690 | 4,250 | 7,921 | 25,500 | 47,011 | 0.32 | 9.60 | 0.09 | 0.76 |
| 850 | 232,600 | 9,000 | 5,000 | 5,000 | 9,320 | 2,400,000 | 2,428,320 | 2.66 | 79.83 | 0.57 | 4.58 |
| 680 | 203,930 | 7,200 | 1,600 | 4,000 | 7,456 | 24,000 | 44,256 | 0.25 | 7.50 | 0.03 | 0.30 |
| 1,020 | 268,570 | 10,800 | 2,400 | 6,000 | 11,184 | 36,000 | 66,384 | 0.33 | 10.05 | 0.03 | 0.25 |
| 1,190 | 242,540 | 12,600 | 2,800 | 7,000 | 13,048 | 42,000 | 77,448 | 0.32 | 9.63 | 0.03 | 0.45 |
| 425 | 315,125 | 4,500 | 1,000 | 2,500 | 4,660 | 15,000 | 27,660 | 0.34 | 10.30 | 0.07 | 2.06 |
| 1,020 | 291,270 | 18,000 | 2,400 | 6,000 | 11,184 | 36,000 | 73,584 | 0.36 | 10.95 | 0.04 | 0.54 |
| 1,360 | 431,760 | 14,400 | 3,200 | 8,000 | 14,912 | 48,000 | 88,512 | 0.52 | 15.61 | 0.04 | 0.60 |
| 263 | 175,713 | 2,790 | 620 | 1,550 | 2,890 | 9,300 | 17,150 | 0.19 | 5.80 | 0.05 | 0.46 |
| 560 | 78,610 | 5,931 | 1,320 | 3,295 | 6,141 | 19,770 | 36,457 | 0.12 | 3.45 | 0.03 | 0.64 |
| 2,097 | 312,247 | 22,212 | 4,900 | 12,340 | 23,001 | 74,040 | 136,493 | 0.45 | 13.50 | 0.02 | 0.48 |
| 8,615 | 2,320,765 | 98,433 | 20,240 | 50,685 | 94,476 | 304,110 | 567,944 | 2.88 | 86.79 | 0.03 | 0.47 |
| 54,360 | 7,171,885 | 582,813 | 500,530 | 533,535 | 596,077 | 4,288,710 | 6,501,665 | 13.64 | 409.8 | 0.03 | 1.01 |

## PRIORITY RANKING

| Watershed | Local | Comprehensive |
|---|---|---|
| **Bituminous Region** | | |
| West Branch (Upstream from Chest Creek) | 5 | 8 |
| Chest Creek | 2 | 4 |
| West Branch (Chest Creek to Clearfield Creek) | 1 | 1 |
| Anderson Creek | 10 | 13 |
| Clearfield Creek | 7 | 10 |
| West Branch (Clearfield Creek to Moshannon Creek) | 9 | 12 |
| Moshannon Creek | 6 | 9 |
| West Branch (Moshannon Creek to Sinnemahoning Creek) | 4 | 7 |
| Sinnemahoning Creek | 8 | 11 |
| West Branch (Sinnemahoning Creek to Bald Eagle Creek) | 11 | 14 |
| Bald Eagle Creek | 12 | 20 |
| West Branch (Bald Eagle to Mouth of West Branch) | 3 | 5 |
| Juniata River Basin | - | 15 |
| Tioga River Basin | - | 2 |
| **Anthracite Region** | | |
| Lackawanna Valley | 8 | 22 |

| Watershed | Local | Comprehensive |
|---|---|---|
| Lackawanna River to Nescopek Creek | 9 | 23 |
| Nescopeck Creek | 7 | 21 |
| Catawissa Creek | 2 | 6 |
| Shamokin Creek | 5 | 18 |
| Mahanoy Creek | 4 | 17 |
| Rausch Creek | 6 | 19 |
| Wiconisco Creek | 3 | 16 |
| Swatara Creek | 1 | 3 |

# CONCLUSIONS

Over 1300 miles of streams in the Susquehanna River Basin are seriously degraded by acid mine drainage. The resultant increase in dissolved solids downstream from New York degrades the quality of the water in the river for use as public water supply.

Stringent requirements for control of stream degradation from active mining activities, imposed by the Commonwealth of Pennsylvania, have greatly reduced the production of acid from these potential sources and will prevent an increase of acid mine drainage. However, acid draining from abandoned mines will not decrease unless remedial action is taken.

Cost estimates for initial abatement work in the Bituminous and Anthracite Regions total $209 million with annual treatment costs in excess of $6.6 million. The total expenditure over a 30 year period is estimated to be $407.7 million. Benefits to accrue over this same 30 year period are estimated to be $520.4 million. Benefits from land improvements alone, in the Bituminous Region, will equal land restoration costs in 34 years. The additional benefits accrued from water quality improvement will decrease the time period considerably to less than 30 years. In the Anthracite Region, where abatement costs are higher, benefits from land improvement alone will equal land restoration costs within 81 years. Substantial benefits from water quality improvements will also decrease the time required to accrue

benefits over costs. The Anthracite Region, when considered by itself, may not present an easily justifiable expenditure. However, acid mine drainage is currently affecting the greater part of the Susquehanna River Basin from New York to Maryland; therefore, the expenditure can be justified on the basis of the overall cost/benefit relationship for both coal regions, which indicates that benefits will exceed the cost in 30 years. The benefit/cost ratios and priorities established in the study provide viable guidelines for logical and orderly development of abatement programs through coordination with all interested agencies.

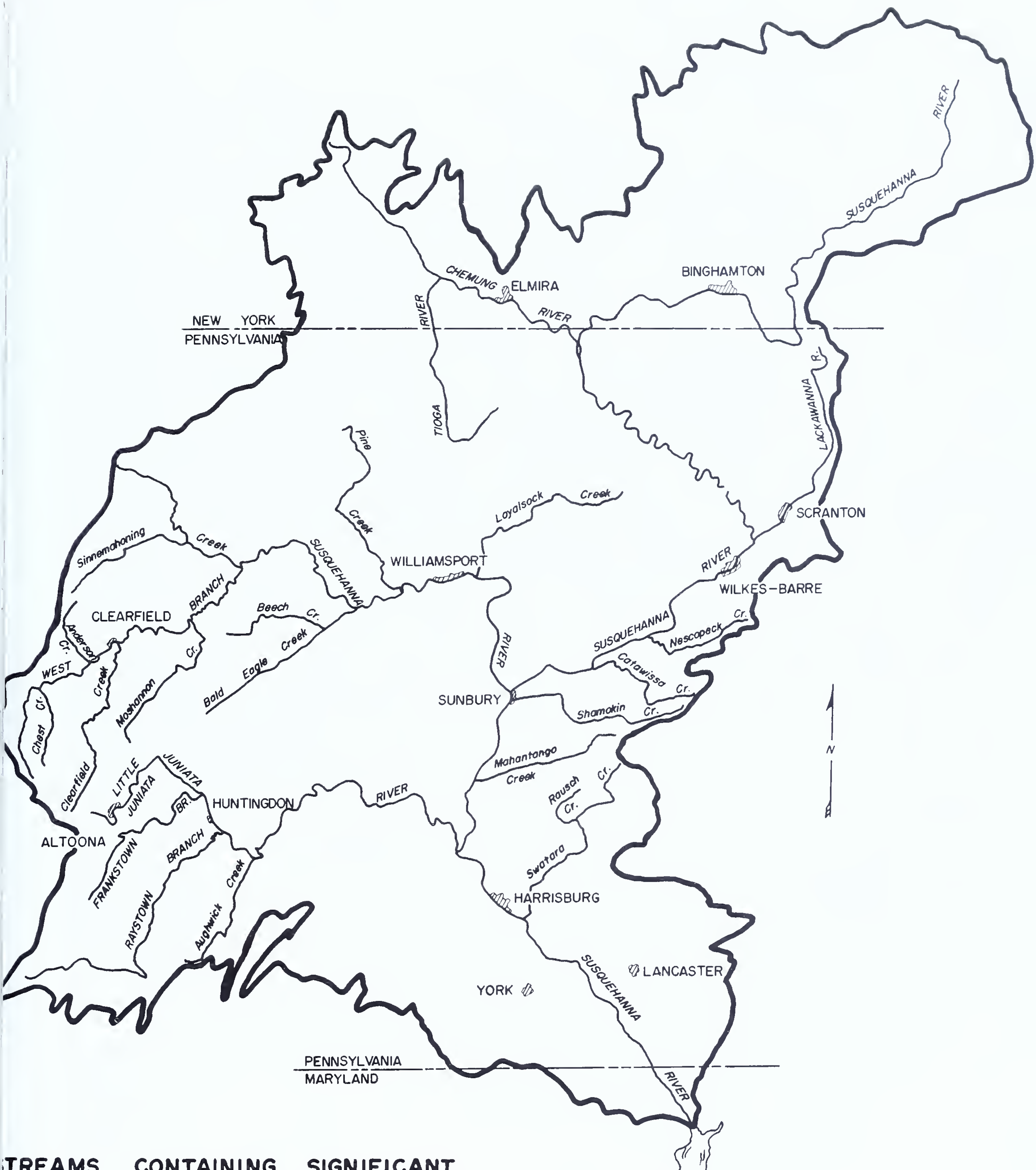
# RECOMMENDATIONS

It is recommended that:

* Coordination be effected with all interested agencies for development and funding of the pollution abatement program.

* An evaluation be made of the subbasins, in order of priority, to determine (1) socio-economic factors, including economic need and development demand, (2) potential land uses, (3) public visibility, (4) the availability of land for restoration, (5) the location and amount of recoverable coal and the potential for it to be mined, and (6) immediate needs.

* Establishment of a detailed acid mine drainage abatement program and priorities.



TREAMS CONTAINING SIGNIFICANT
MOUNTS OF COAL MINE DRAINAGE